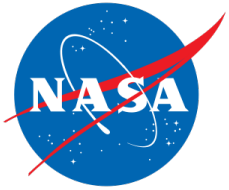
An Introduction to Remote Sensing

NASA Remote Sensing Training
Geo Latin America and Caribbean Water Cycle capacity Building Workshop
Colombia, November 28-December 2, 2011

ARSET

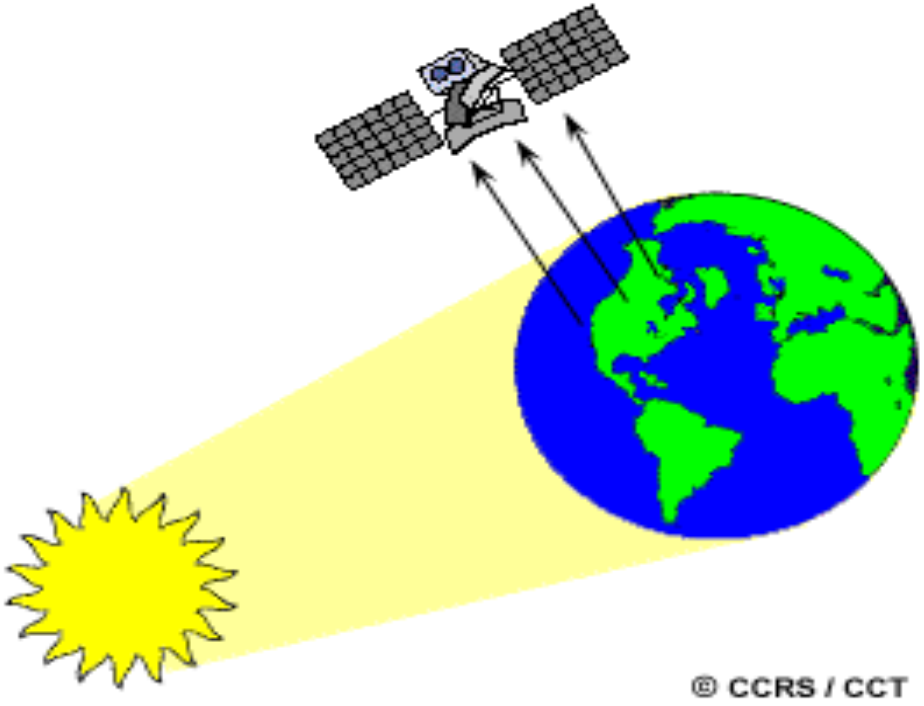
Applied REmote Sensing Training

A project of NASA Applied Sciences

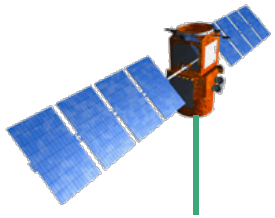


What is Remote Sensing?

Remote sensing is a method of obtaining information about the properties of an object without coming into physical contact with it.



Why use Remote Sensing to Study the Earth ?



- Provides visual Global information
- Complements ground-monitoring networks or provides information where there are no ground-based measurements
- Provides advance warning of impending environmental events and disasters.

How Do Satellites Make Measurements?

- Passive satellite sensors measure radiation reflected or emitted by the earth-atmosphere system
  - Radiance

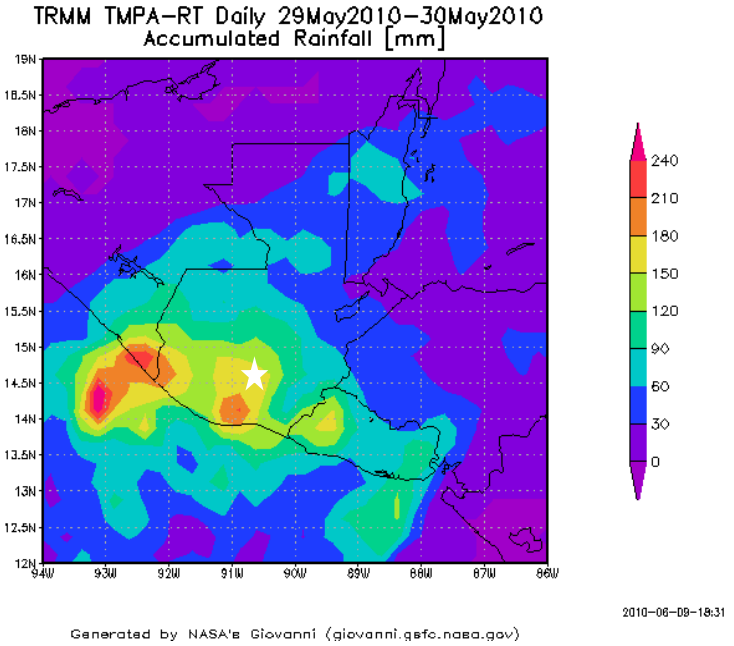
- Radiance is converted to a geophysical parameter.

Examples:

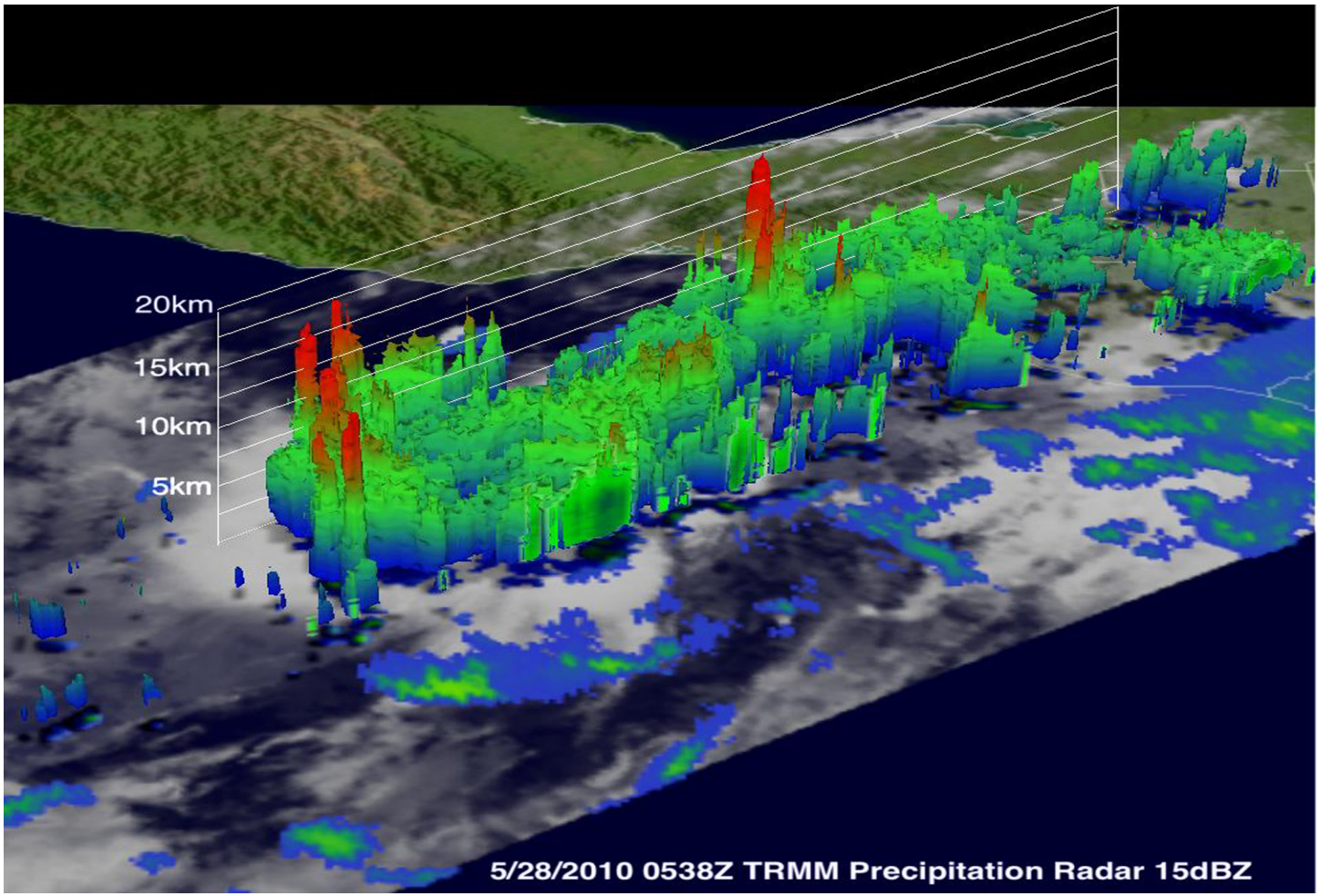
Accumulated Rainfall

Snow Cover

Accumulated Rainfall Guatemala

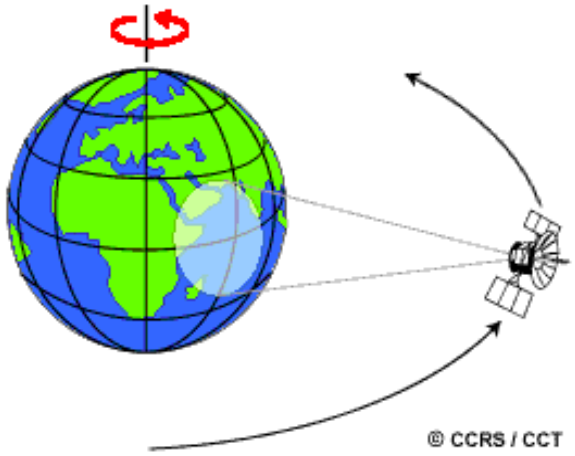


Example of Remote Sensing Product Precipitation Radar from TRMM (Guatemala)



Types of satellite orbits

Geostationary orbit



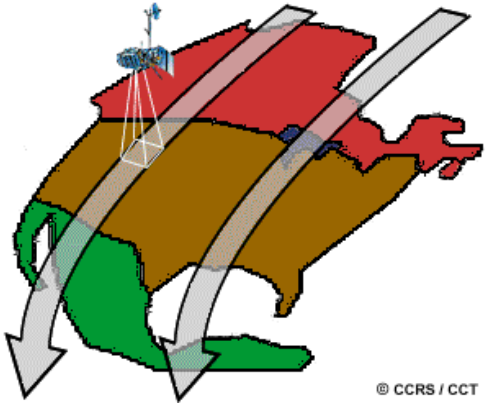
Fixed’ above earth at ~36,000 km

Frequent Measurements

Limited Spatial Coverage

Low Earth Orbit (LEO)

- **Polar (Aqua, Terra)**
- **Nonpolar (TRMM)**

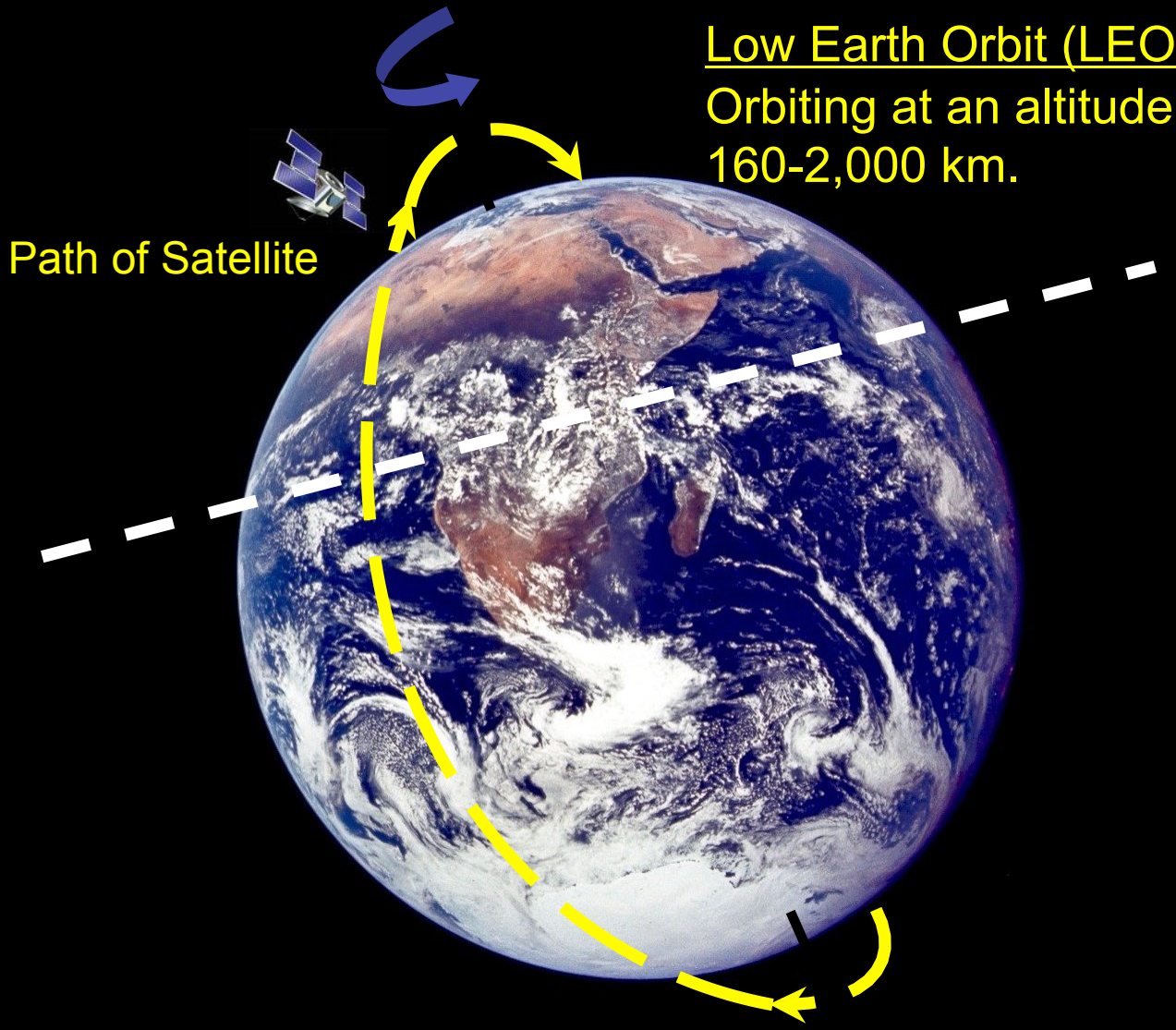


Circular orbit constantly moving relative to the Earth at 160-2000 km

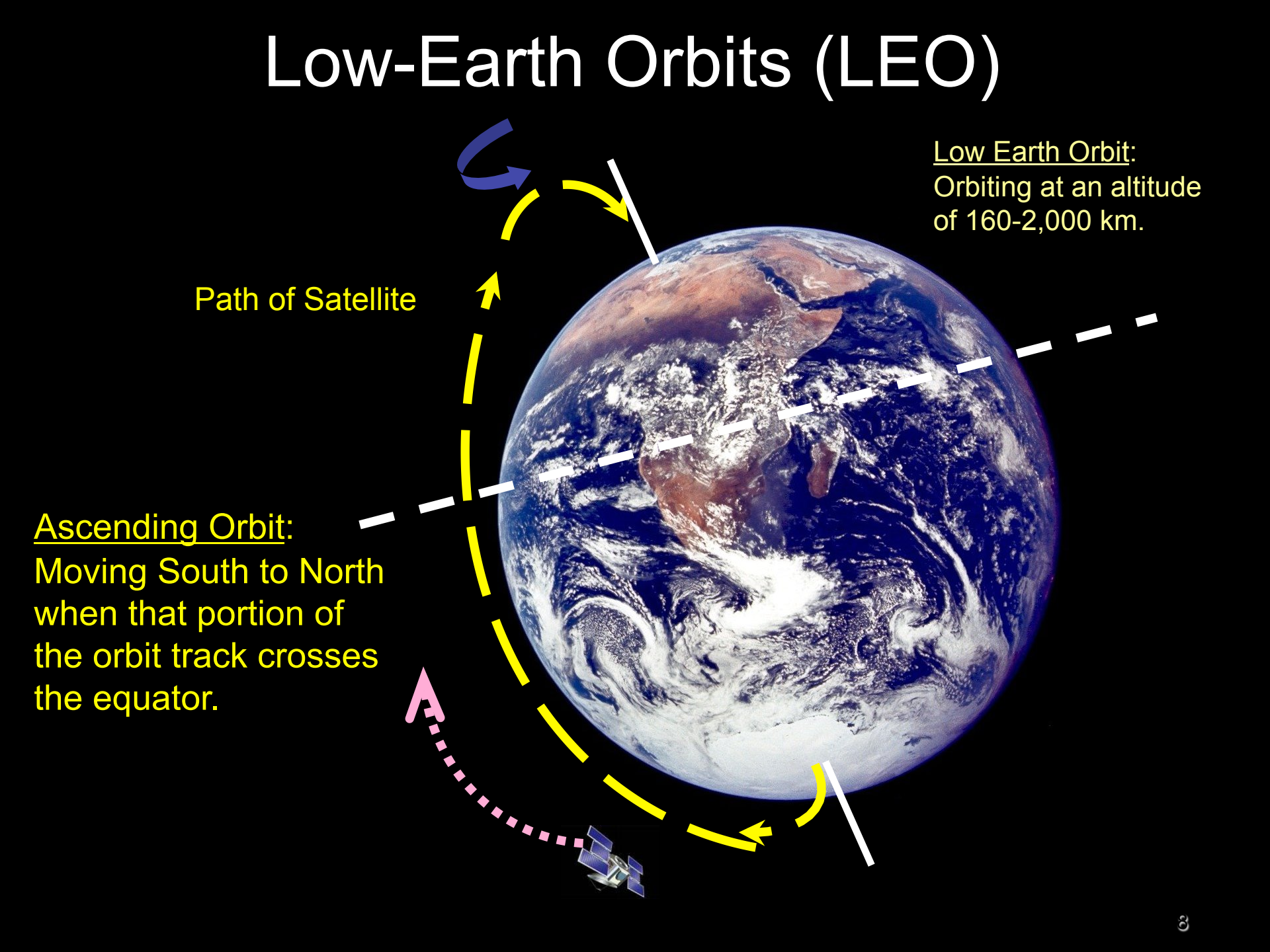
Less Frequent measurements (< 2 times per day)

Large (global) spatial Coverage

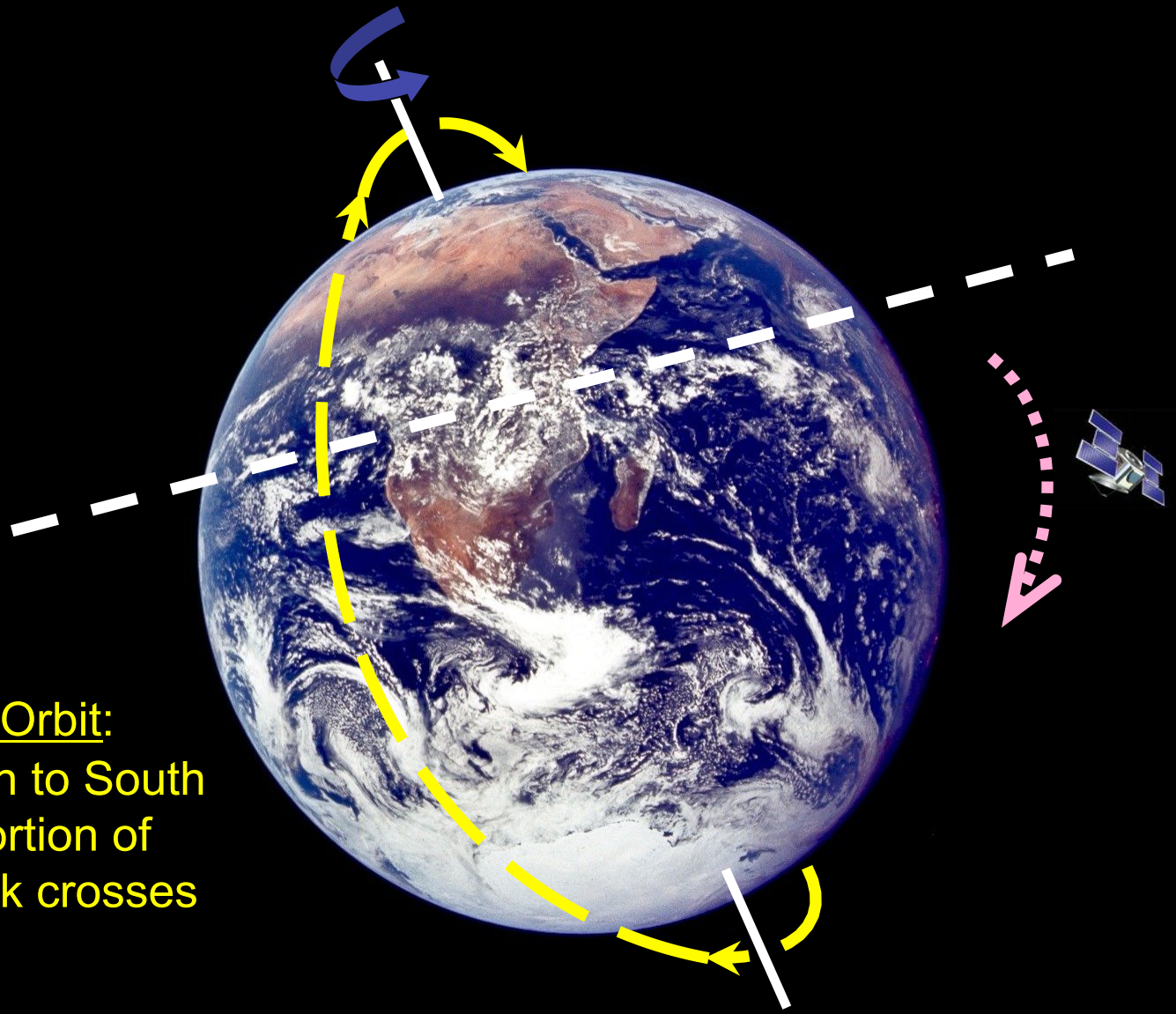
Low-Earth Orbits (LEO)



Low-Earth Orbits (LEO)

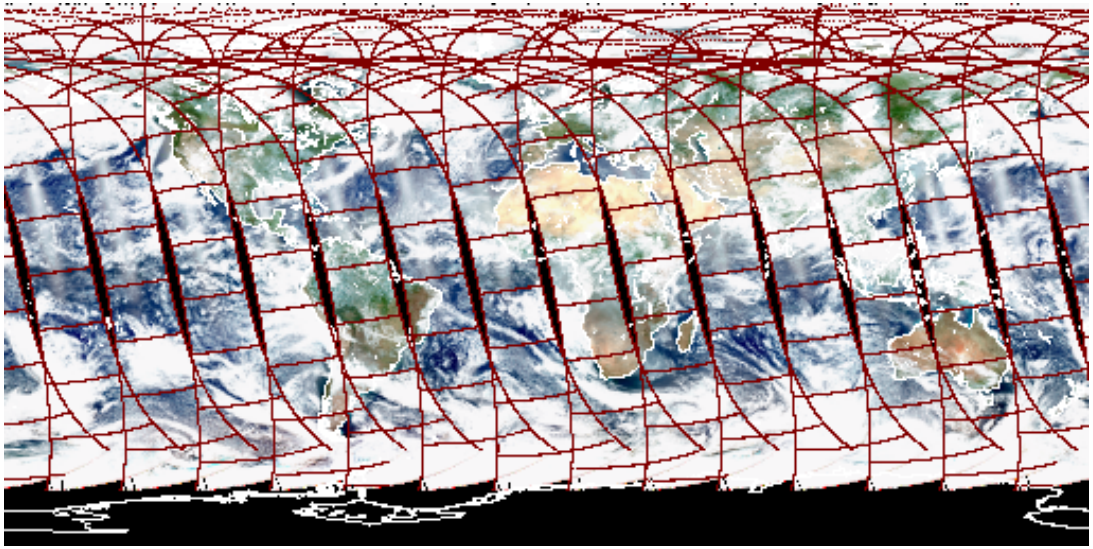


Low-Earth Orbits (LEO)



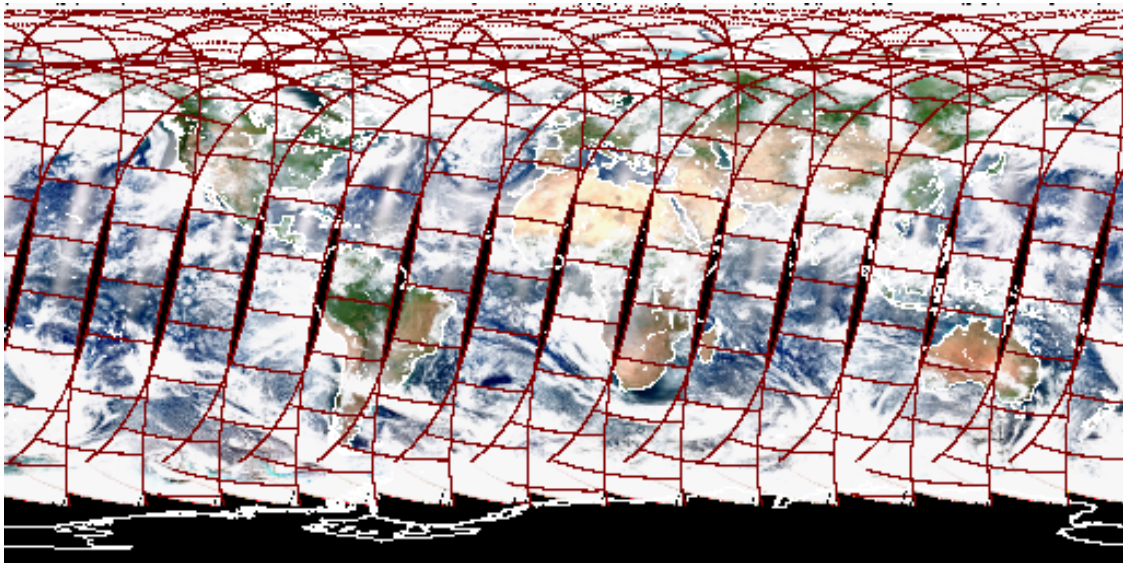
Descending Orbit: Moving North to South when that portion of the orbit track crosses the equator.

Aqua (“ascending” orbit) day time



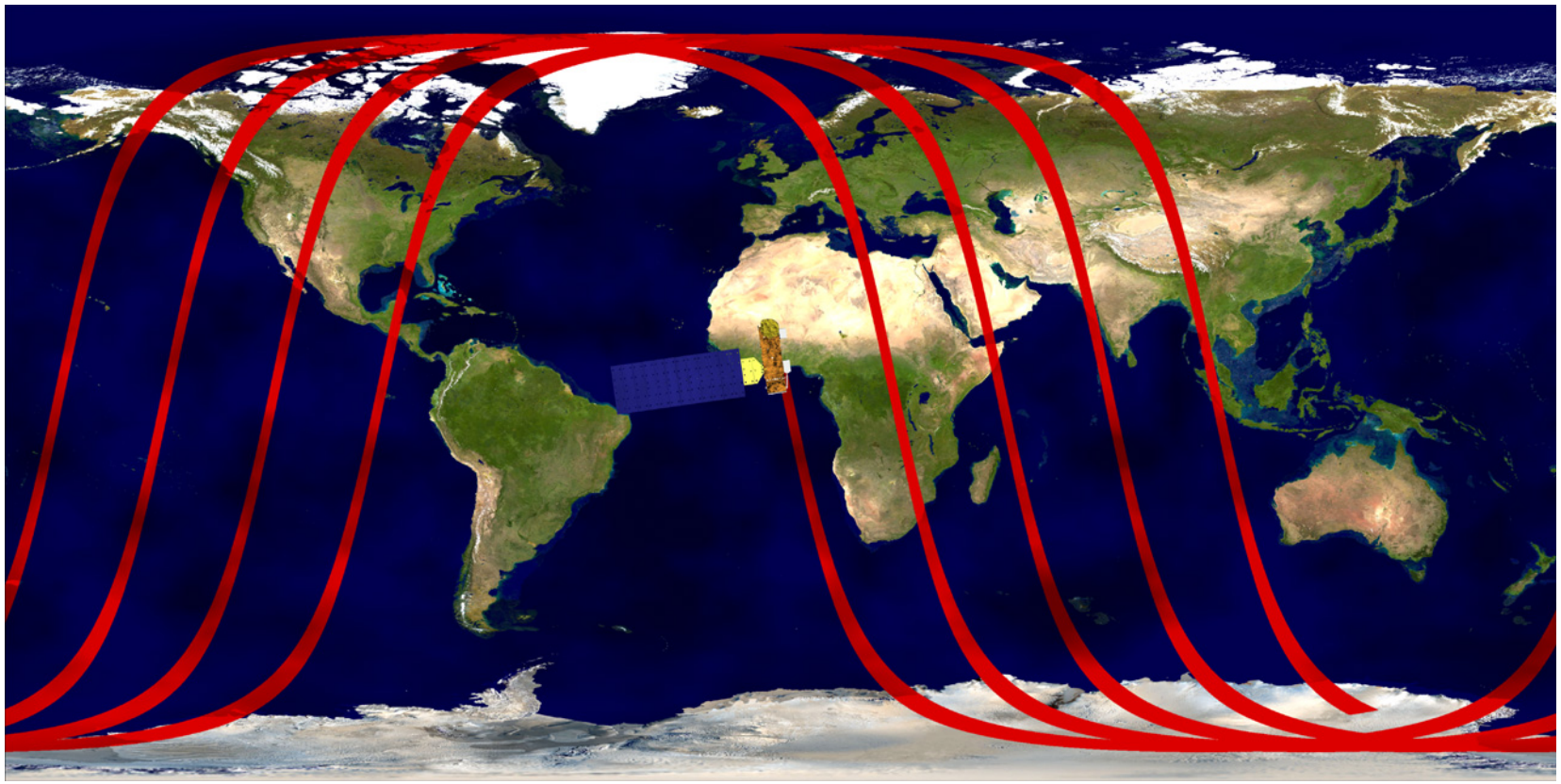
LEO Polar Orbiting

Terra (“descending”) Day time



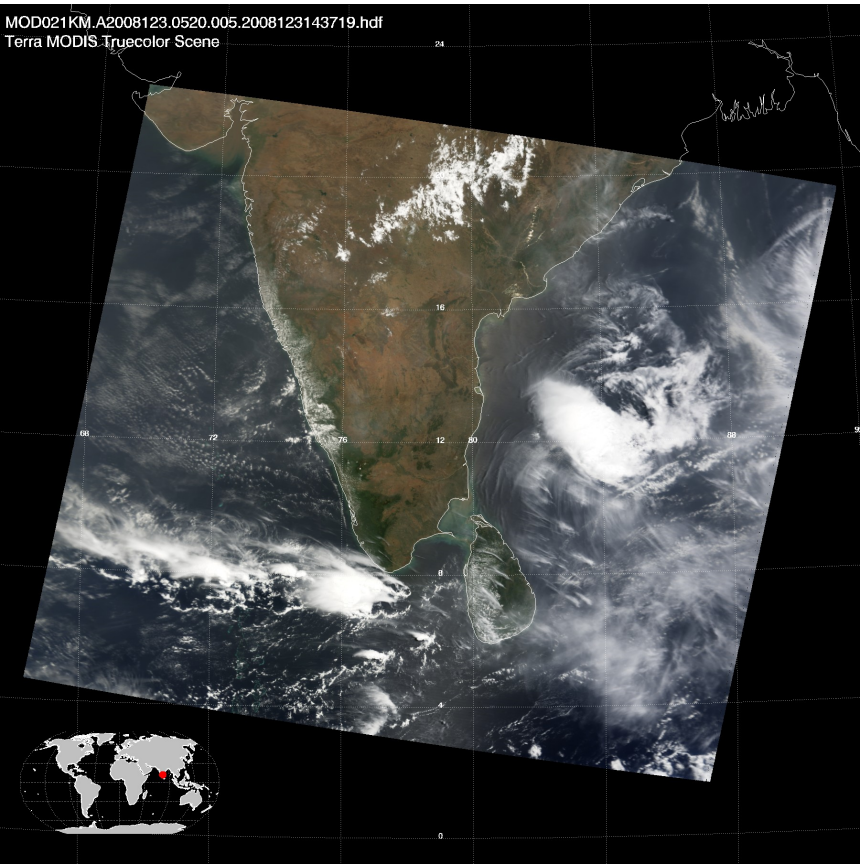
Aqua's Orbit

- Near-polar, sun-synchronous, orbiting the Earth every 98.8 minutes, crossing the equator going north (daytime ascending) at 1:30 p.m. and going south (night time descending) at 1:30 a.m.
- The orbit track changes every day but will repeat on a 16 day cycle. **This is true for Aqua, Terra, and TRMM.**

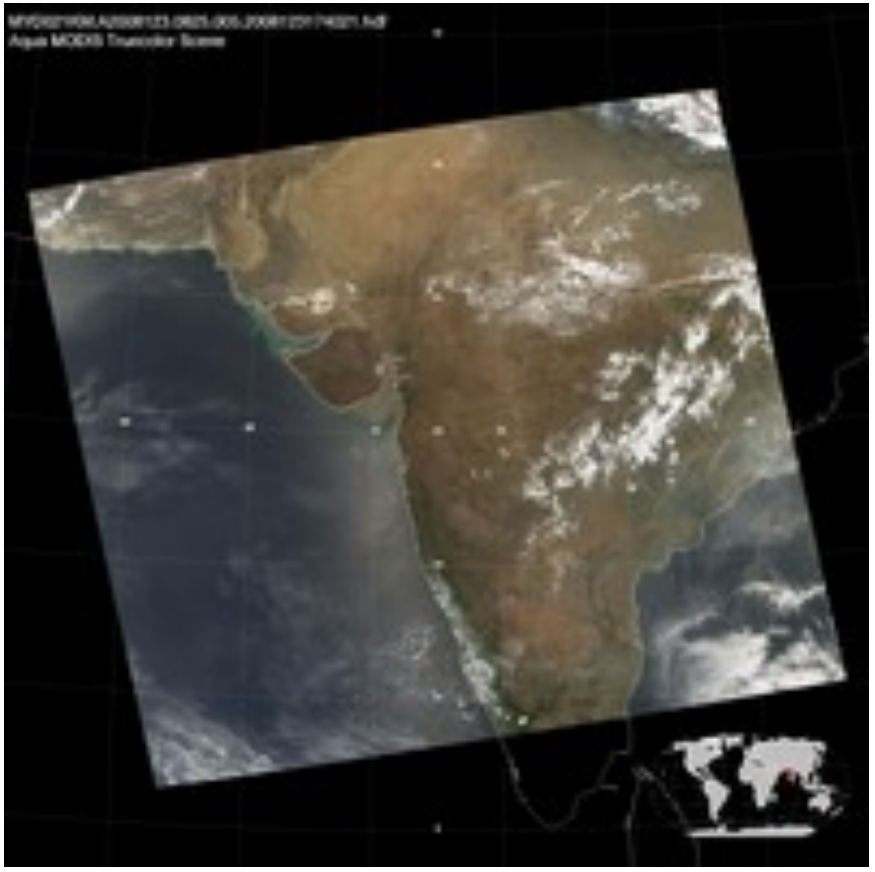


Daytime Orbits

Terra - Descending



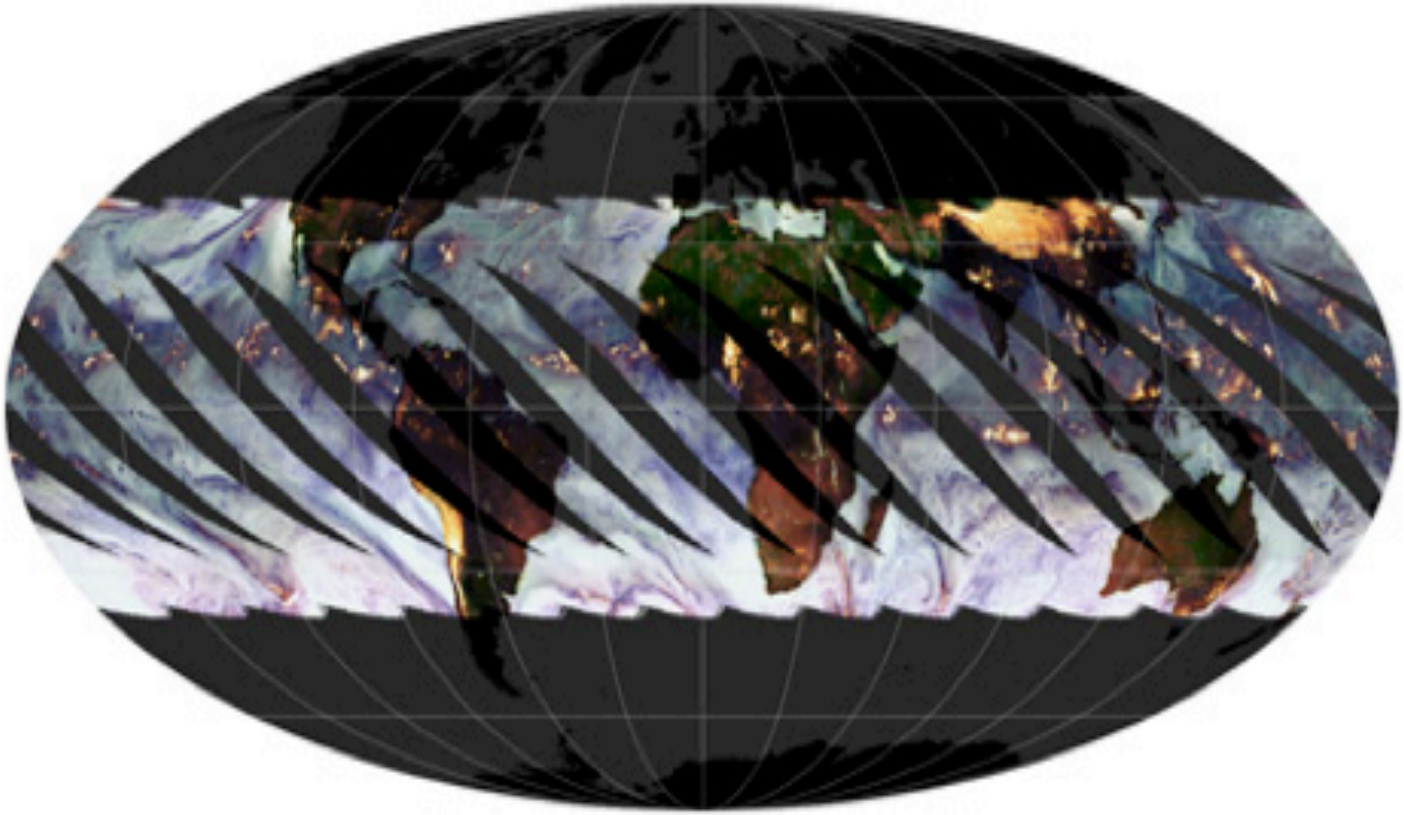
Aqua - Ascending



When looking at an image of a piece of the orbit the two sensors will have opposite ‘tilts’.

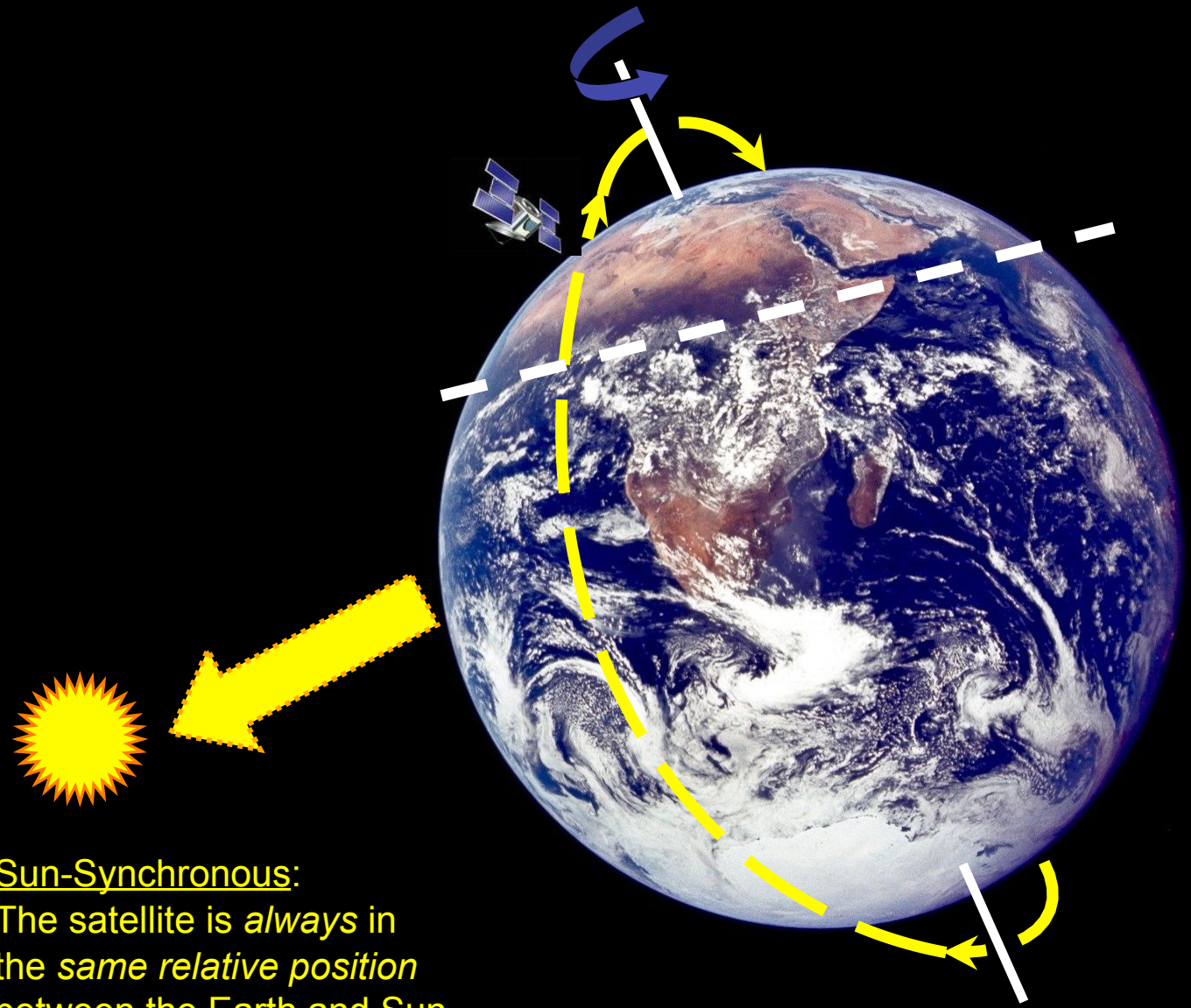
LEO nonpolar Orbiting

TRMM ("ascending" orbit)



TRMM's Low orbit allows its instruments to concentrate on the tropics. This image shows half the observations TRMM makes in a single day

Earth-Observing Satellites



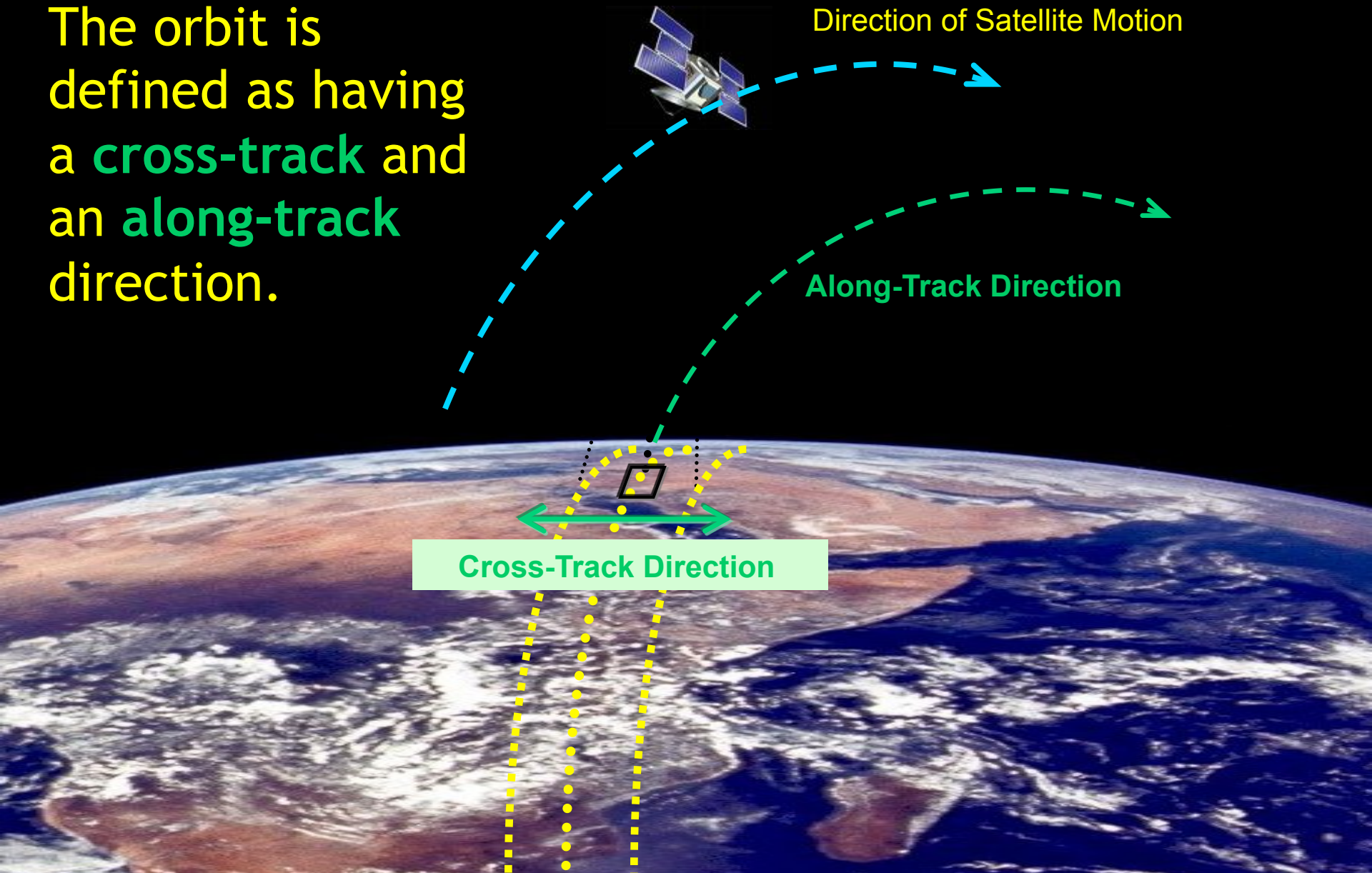
Equator-Crossing Time: The local apparent solar time when the satellite crosses the equator.

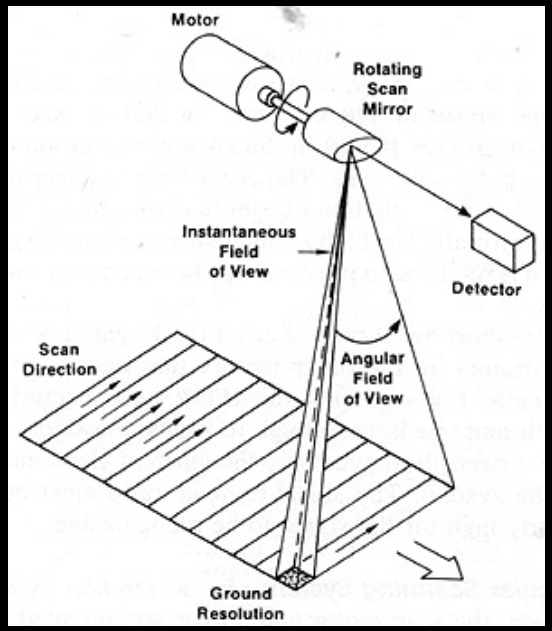
Example: Terra has an equatorial crossing time of 10:30 am, and is called an "AM" or morning satellite.

Sun-Synchronous: The satellite is *always* in the *same relative position* between the Earth and Sun

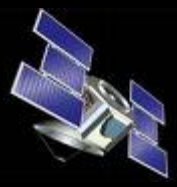
Field-of-View (FOV)

The orbit is defined as having a cross-track and an along-track direction.





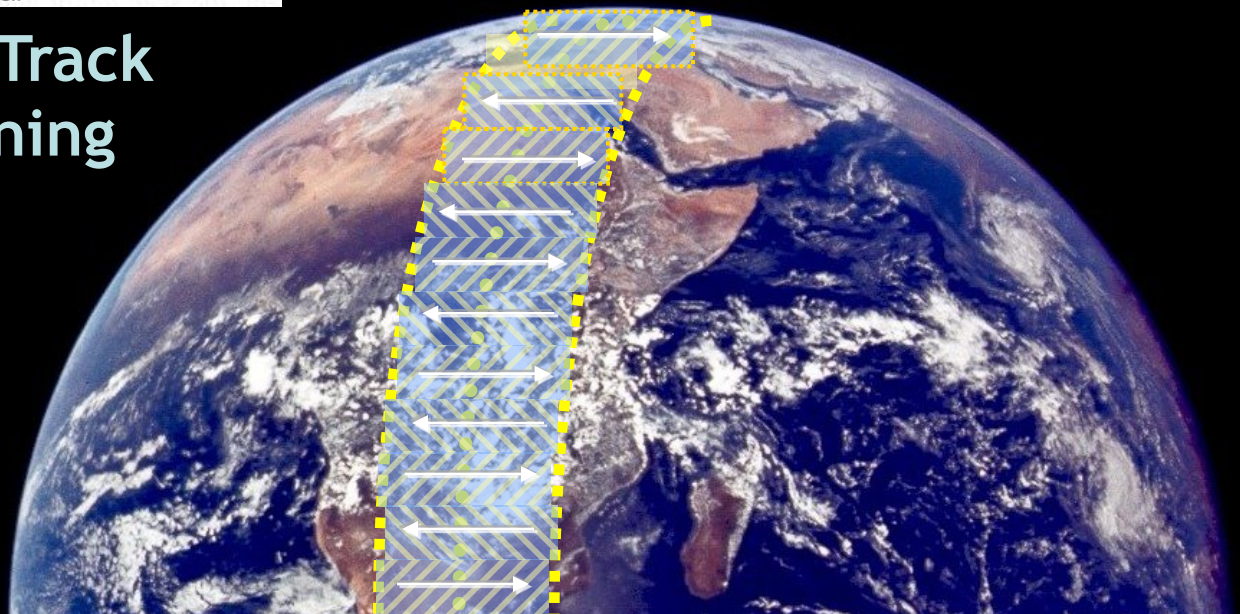
Cross-Track Scanning



Direction of Satellite Motion

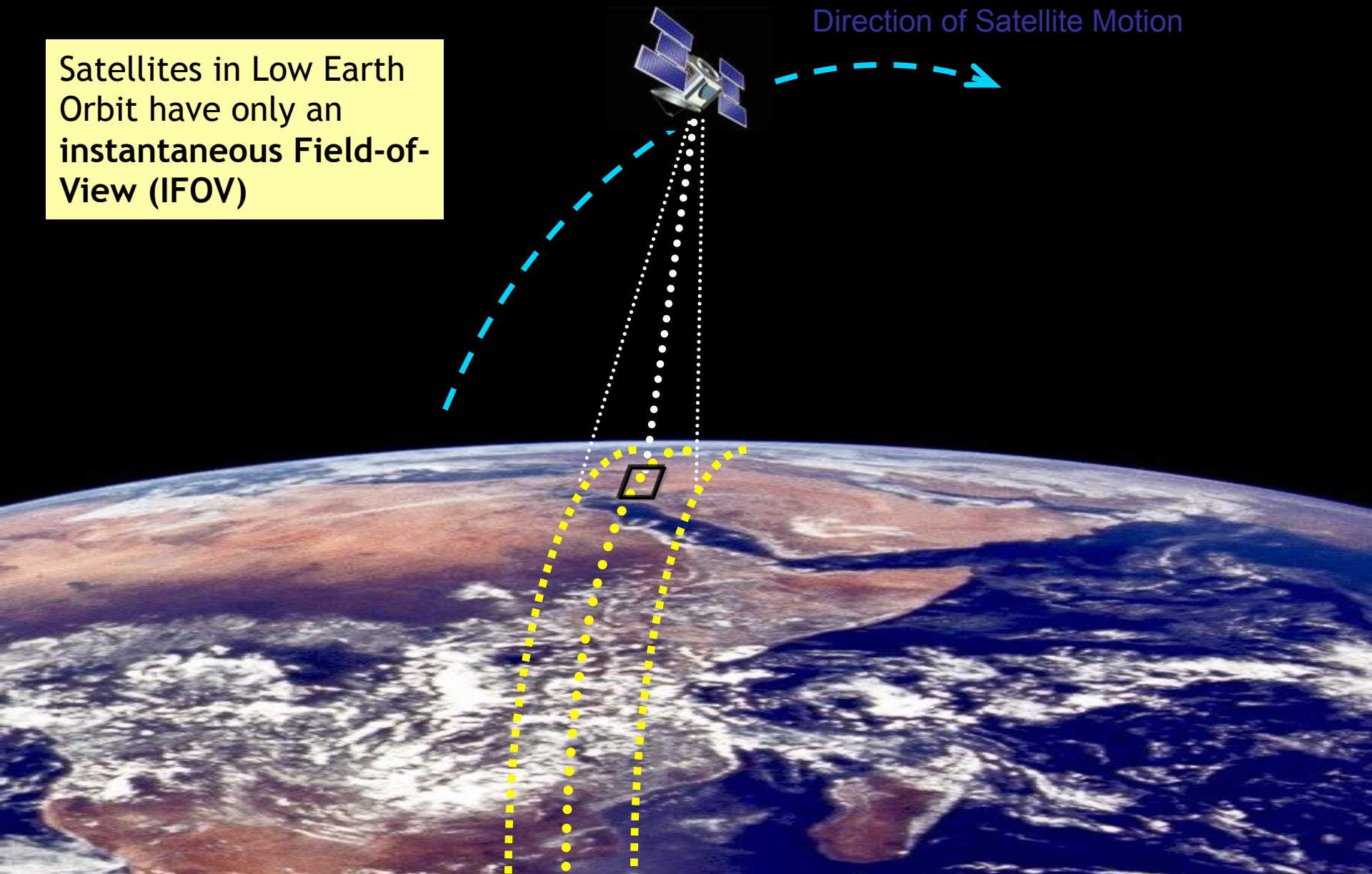
"Cross-Track Scanning," Scan mirror swings back and forth.

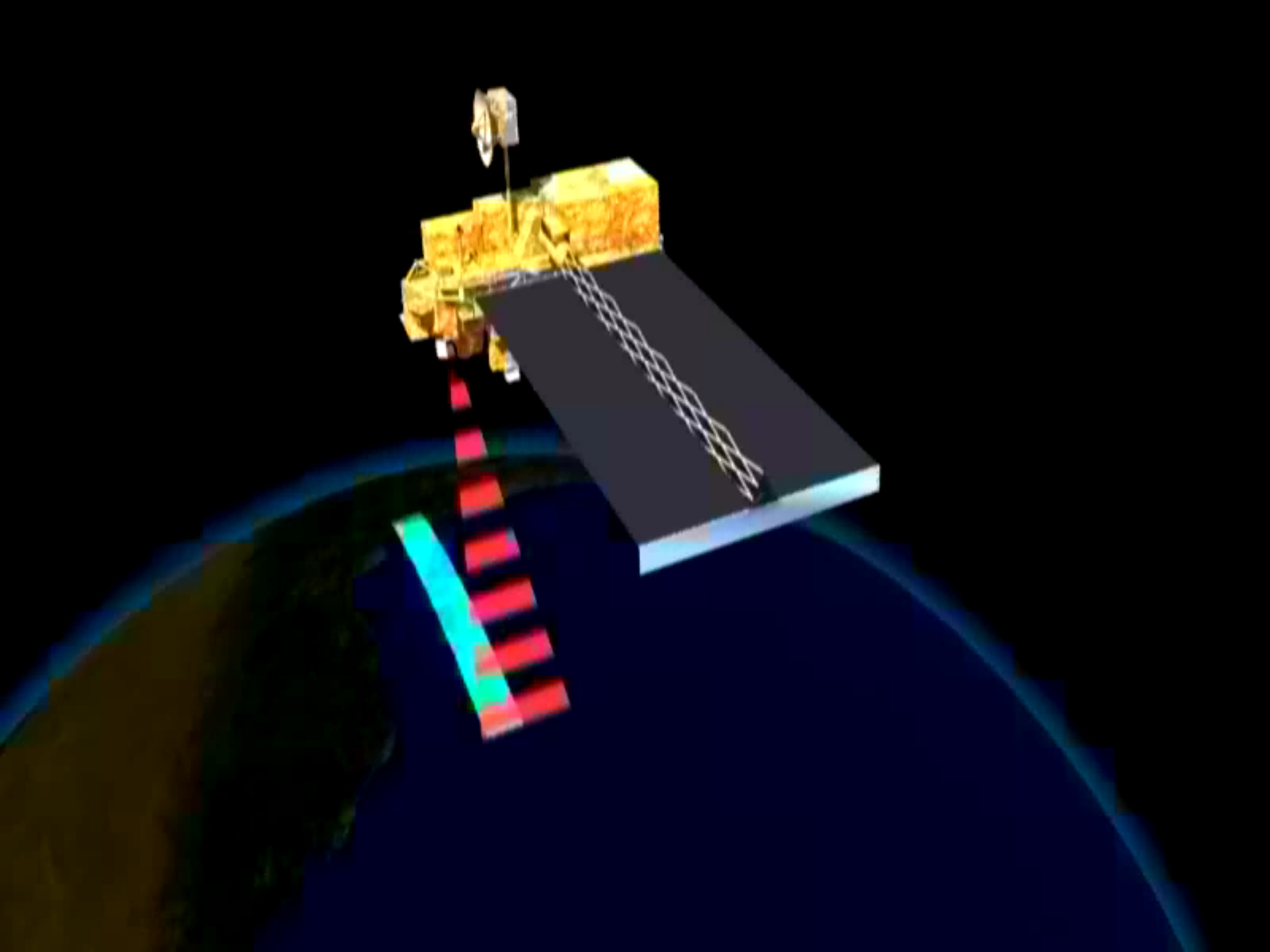
Sensor observes pixels in sequence across track and along the direction of the satellite's motion.



LEO Field-of-View (FOV)

Satellites in Low Earth Orbit have only an **instantaneous Field-of-View (IFOV)**



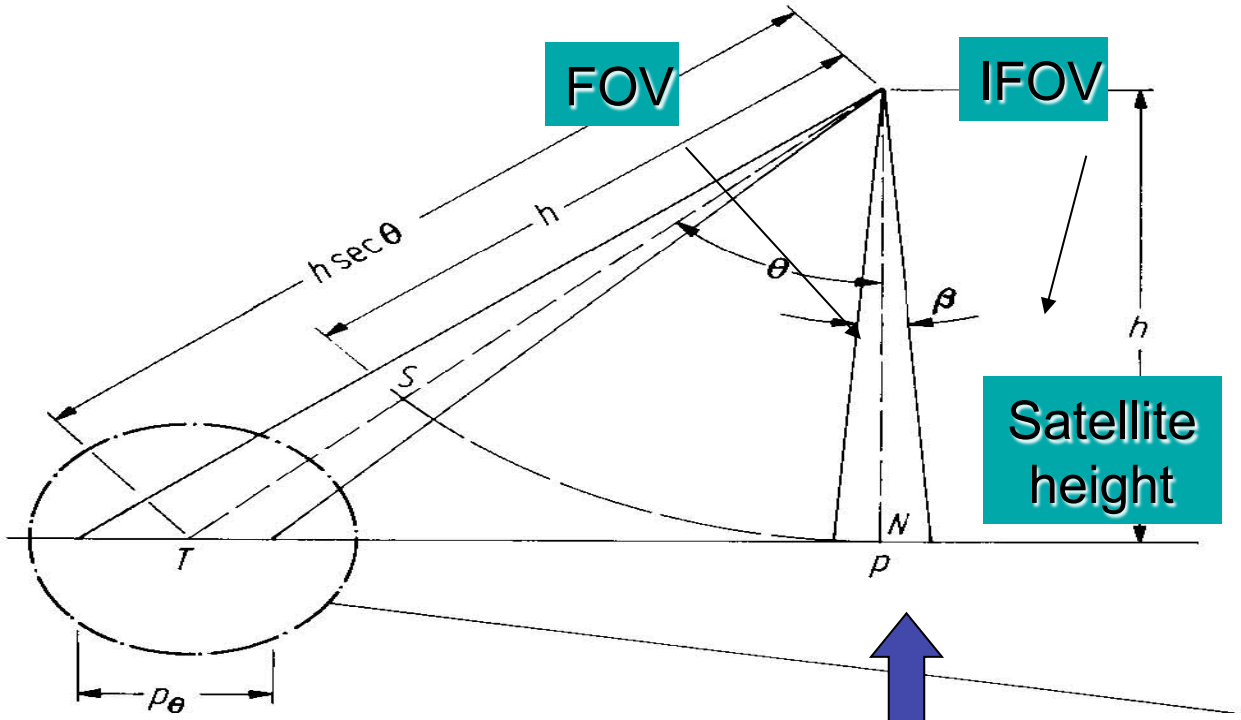


Remote Sensing Resolutions

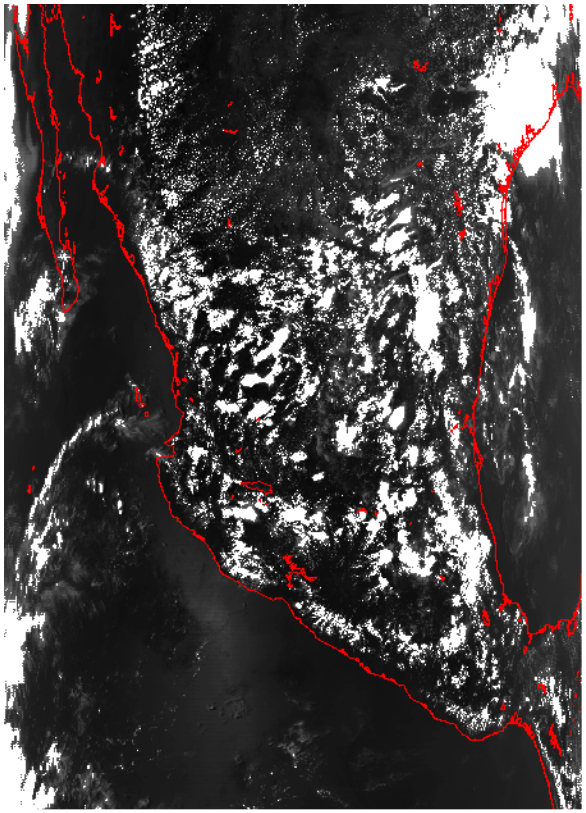
- **Spatial resolution**
- **Temporal resolution**
- Spectral resolution
- Radiometric resolution

Spatial Resolution

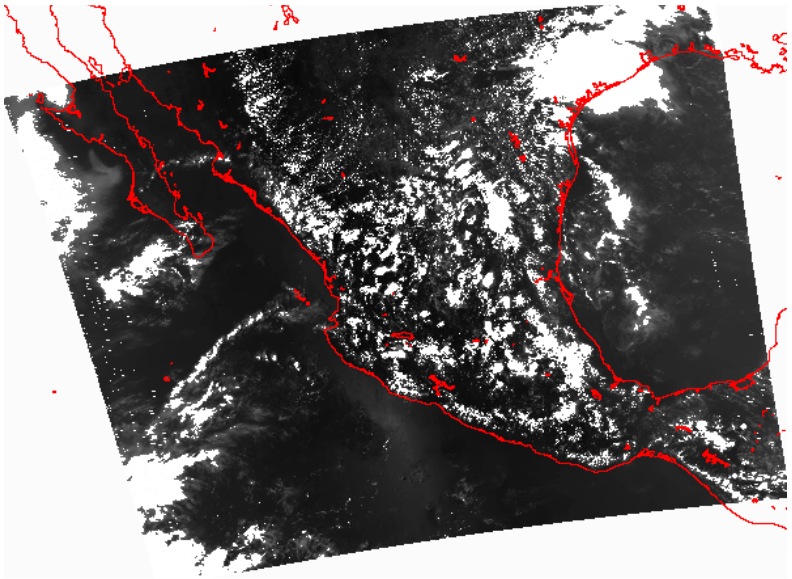
- Spatial Resolution : A simple definition is the pixel size that satellite images cover.
- Satellite images are organized in rows and column called raster imagery and each pixel has a certain spatial resolution.



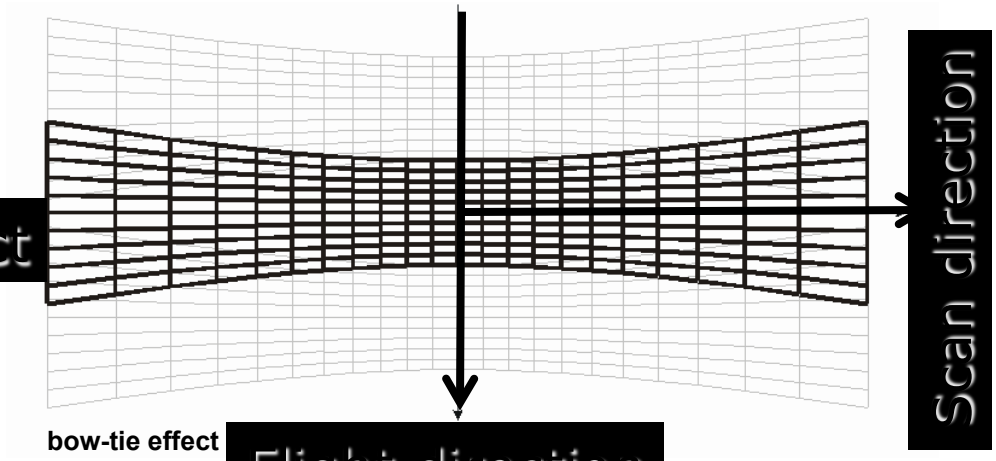
Native satellite view vs. map projection



cylindrical isotropic projection



increasing pixel size



Spatial Resolution of NASA Satellite Data Products

- **High Spatial resolution**
  250x250m; 500x500 m; 1x1 km; 0.05x0.05 degrees
  Example: MODIS True Color Imagery (RGBs)

- **Moderate Spatial Resolution**
  0.25x0.25 degrees
  Example: TRMM precipitation products.

- **Low Spatial Resolution (Level 3)**
  Primarily at 1 x 1 degree - derived from each data set's native resolution product
  Example: AIRS surface air temperature

Example: NASA High Spatial Resolution Product

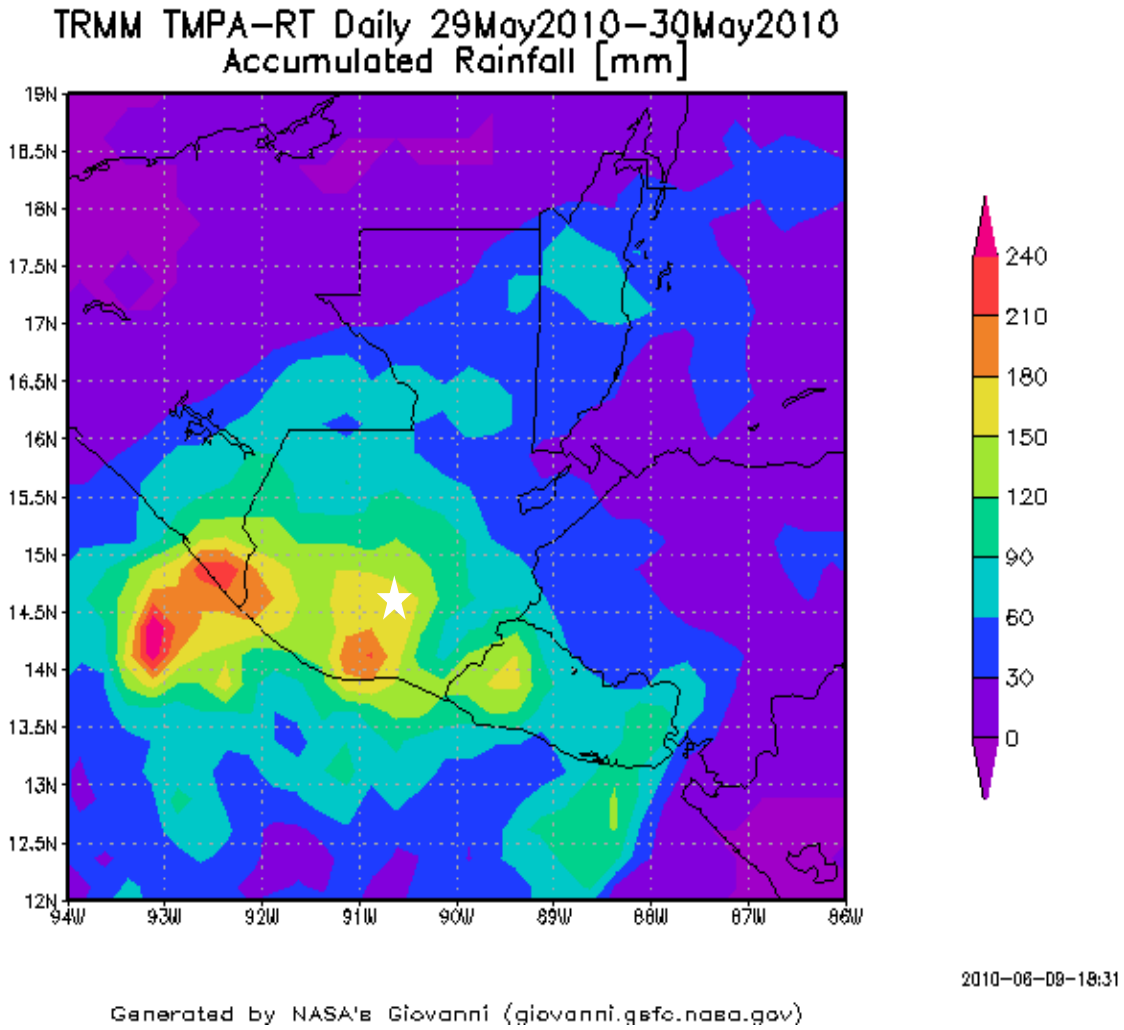
2x2 km resolution
MODIS TERRA

True Color Image over Southern California

January 4th, 2009

Source: NASA GSFC Rapidfire AERONET Subset for Fresno, CA

Example: NASA Moderate Spatial Resolution Product

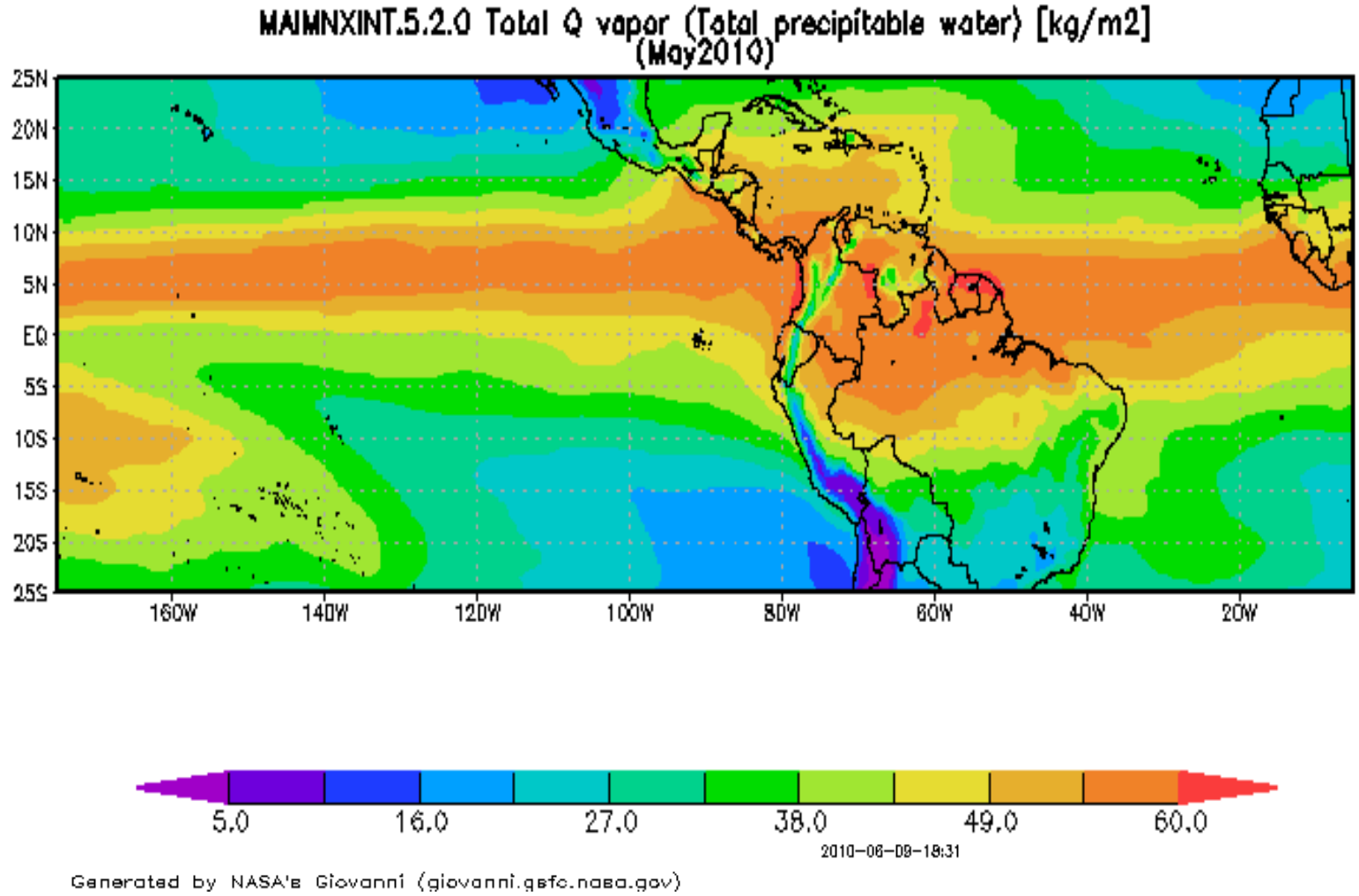


0.25x0.25 degree TRMM

Accumulated Rainfall over Guatemala

Example: NASA Low Spatial Resolution Product

MERRA Monthly Precipitable Water 1.25 x 1.25 Degrees



Temporal Resolution of Remote Sensing Data

The frequency at which data are obtained is determined by:

- Type and height of orbit
- Size of measurement swath

Temporal resolution of Polar Orbiting Satellites Example: Terra, Aqua

- Observations available only **at the time of the satellite overpass.**
- IR based observations available 2X a day (AIRS)
- Visible observations available 1X a day
- Polar regions may have several observations per day.

Temporal resolution of nonpolar satellites
Example: TRMM

- Observations available only **at the time of the satellite overpass.**
- Observations available less than once a day

Note: derived products available at 3-hourly

Remote Sensing - Resolutions

Spectral resolution – The number and range of spectral bands.

More bands = More information

Radiometric resolution – The bandwidth of the individual spectral bands. Important for avoiding or taking advantage of "atmospheric windows"

Satellite data levels of processing and formats

Levels of Data Processing

Level 1	Source Data: L1a are raw radiance counts and L1b are calibrated radiances (after applying calibration to L1a)
Level 2	Derived geophysical variables at the same resolution and location as Level 1 source data (after applying atmospheric correction, etc.)
Level 2G	Level 2 binned data mapped on a uniform space-time grid (*Example: OMI Tropospheric NO2 at 0.25x0.25 degree resolution)*
Level 3	Geophysical variables mapped on a uniform space-time grid in derived spatial and/or temporal resolutions *(Example: MODIS Temperature at1x1 degree resolution)*

Levels of Data Processing and Spatial Resolution

- **Level 1 and Level 2** data products have the highest spatial and temporal resolution

- **Level 3 products** are derived products with equal or lower spatial and temporal resolution than Level 2 products. Available hourly, daily and for some products also monthly

Levels of Data Processing

Level 1 Products

Orbital data

Used to produce

Level 2 Products

Orbital data

Used to produce

Level 3 Products

Global composites
of level 2 products

Less Processing

More Processing

Levels of Data Processing

Level 1 Products

Orbital data

Used to produce

Level 2 Products

Orbital data

Used to produce

Level 3 Products

Global composites of level 2 products

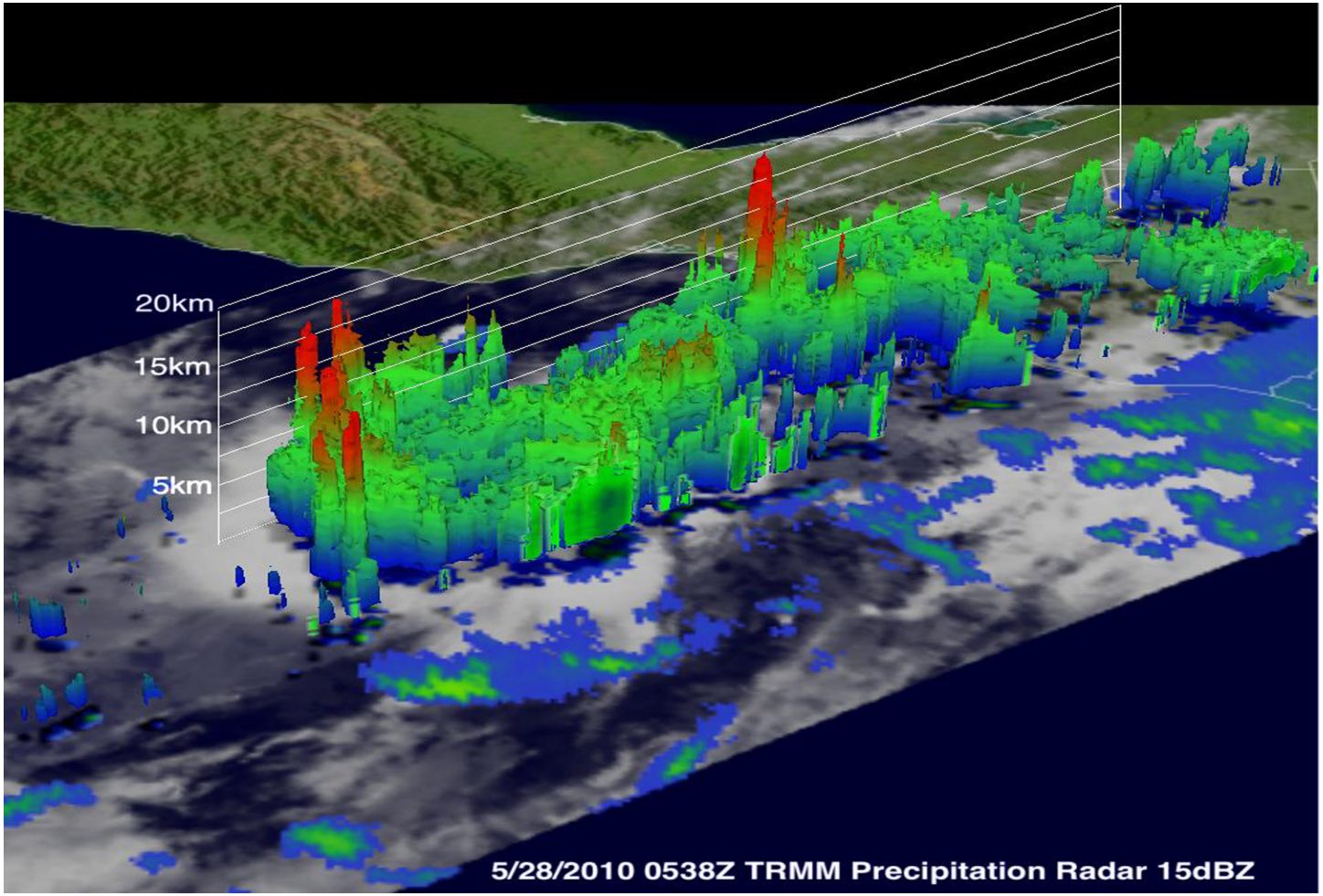
More User Control

Less User Control

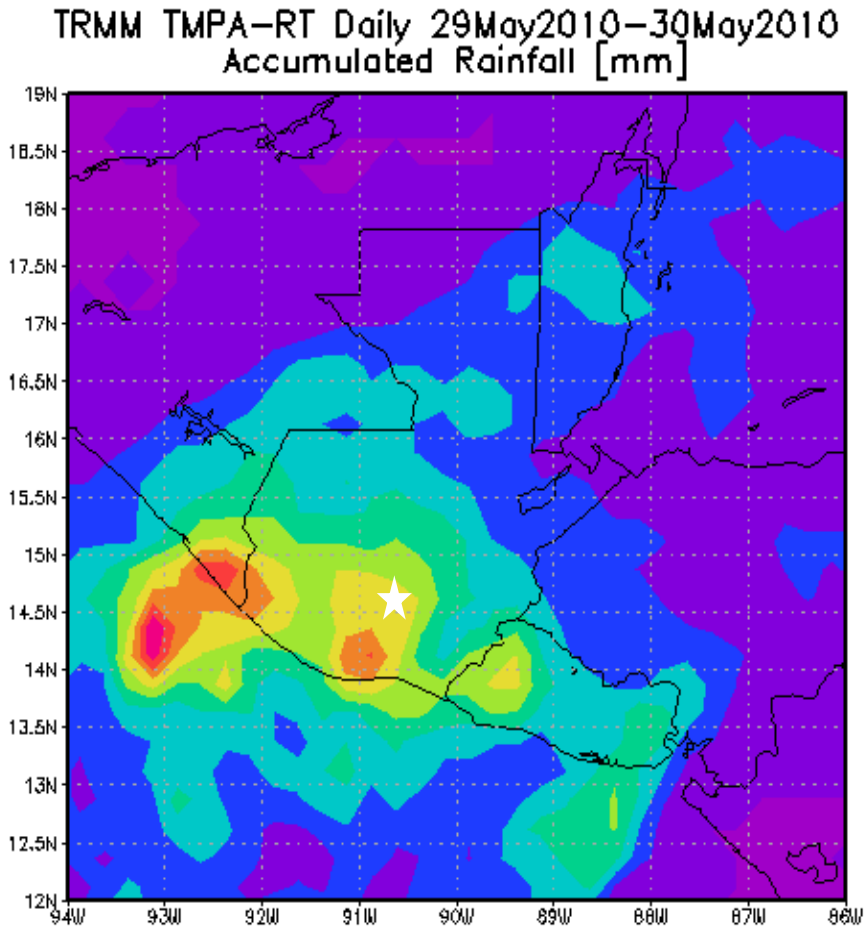
Harder to Use

Easier to Use

Level 2 Example: Guatemala Precipitation Radar from TRMM (4x4 km)



Level 3 Example: TRMM Accumulated Rainfall



0.25x0.25 degree TRMM

Accumulated Rainfall over Guatemala

Important Terms for Level 2 and Level 3 Products

Reprocessing: Applying a new algorithm to and entire data set.

Forward Processing: Applying the current algorithm to newly acquired data.

Data Versions

- For some NASA data products more than one version may be available
- Note: Giovanni products are the most recent data version publicly available
- For each level of processing versions of data are periodically released as retrieval algorithms or other sources of information improve, e.g. V001, V002, V003

Data Formats

- **Text/ASCII**

  pros: easy to read and examine the data right away (can read with used tools such as excel and GIS software)

  cons: large data files
- **Binary – HDF, NetCDF**

  pros: takes less space, more information (metadata,SDS)

  cons: need specific tools or code to read the data
- **KML or KMZ (zipped KML)**

  pros - easy 2D and 3D visualization of the data through free tools such as Google Earth. Data are very low volume

HDF Data Formats

HDF is the standard format for most NASA data

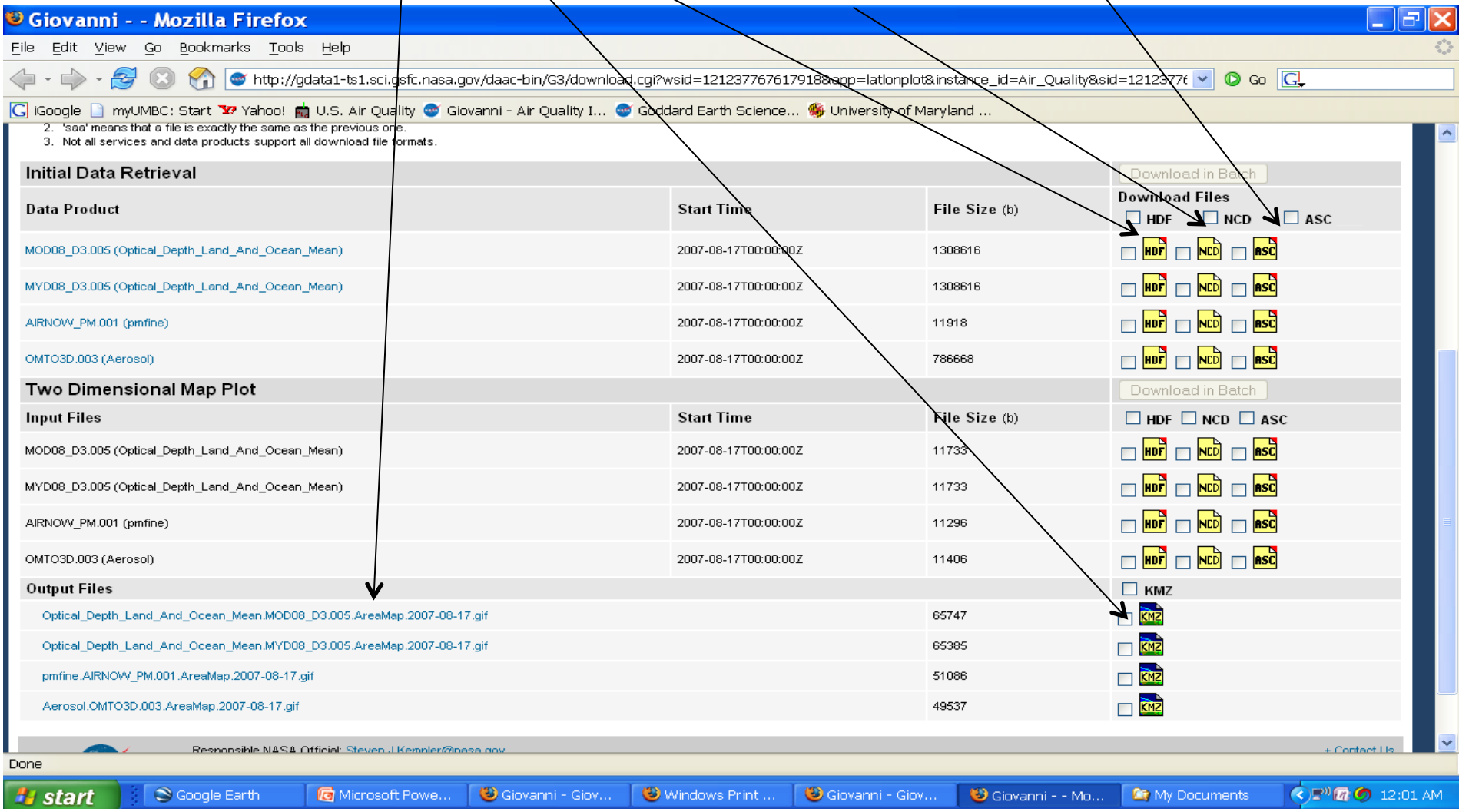
HDF files contain both data and metadata

SDS - Each parameter within an HDF file is referred to as an SDS (Scientific Data Set)

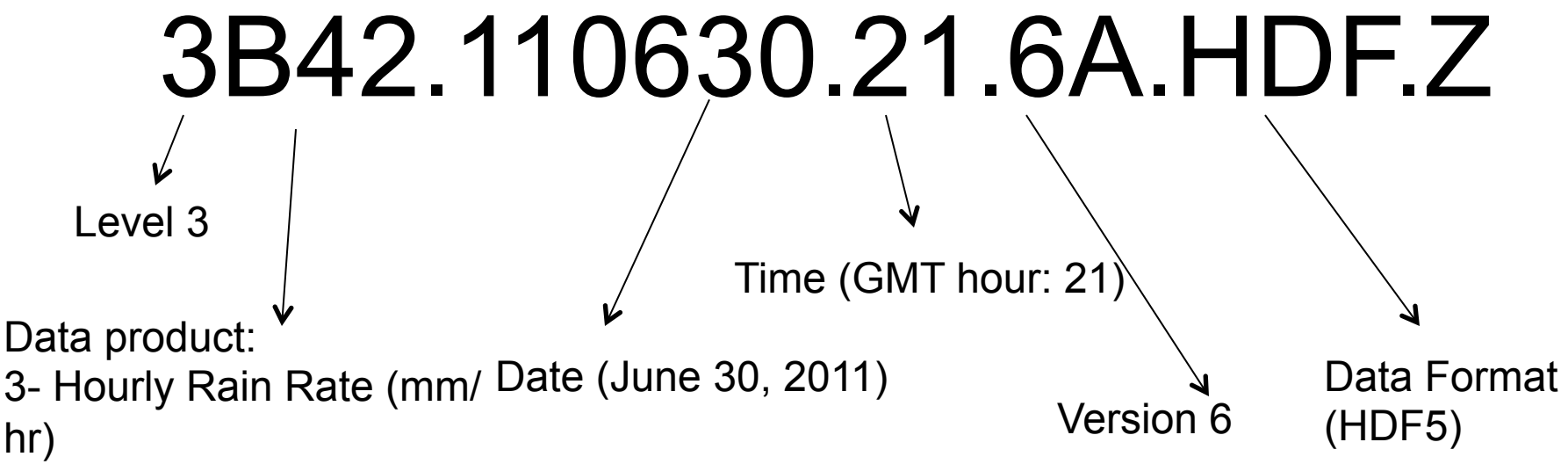
An SDS must be referenced precisely according to name when analyzing the data with your own computer code.

Accessing different data formats (Example: Giovanni Download Page)

GIF KMZ HDF NetCDF ASCII



Putting it all together: data file names



Data format is HDF5
Level of Processing is L3
Version 6

Conclusions

- NASA satellite data formats are varied and the most appropriate depends on specific user needs

- Available data formats include, ASCII, HDF, NetCDF, and KMZ

- Satellite data vary in spatial resolution depending on instrument characteristics and the level of processing (L2, L2G, L3)